



**TREE MULBERRY
SUSTAINABLE AND ECONOMICALLY VIABLE
SERICULTURAL FARMING FOR SOUTHERN TROPICAL ZONES**

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Abstract

Traditional paired row system of mulberry plantation raised in [(3'x2')x5'] spacing accommodating 13,888 plants/hectare as low bush plantation resulted in practical problems viz. difficult to cultivate in limited water resource, prevents mechanization, inconvenient for cultural and intercultural operations, susceptible for drought stricken conditions, involves manpower drudgery and prevents silkworm rearing during summer period due to low and poor quality leaf production. Therefore, tree mulberry farming accommodating limited number of plants grown in wider spacing supplementing limited water, manure and fertilizer inputs with reduced manpower drudgery is gaining popularity among the Southern Tropical Zones. Keeping the above thrust area of research, efforts were made to develop suitable and sustainable tree mulberry farming technology for enhanced quality leaf production was attempted. It was noticed that tree mulberry raised in wider spacing (8'x3') accommodating 4547 plants/ha yielded higher leaf (67,072kg/ha/yr) over the traditional paired row spacing [(3'x2')x5'] with 13,888 plants/ha (60,144kg/ha/yr) followed by (8'x5') spacing with 2728 plants/ha (51,174kg/ha/yr). However, 10'x10' spacing with 1093 plants resulted in 70% reduction of leaf yield (21,084kg/ha/yr) indicating that economically not viable for the welfare and benefit of sericulturist. Other plant growth and leaf quality parameters also indicated the similar trend.

Keywords Mulberry, leaf yield, silkworm rearing, spacing.

I. INTRODUCTION

In India, mulberry (*Morus alba* L.) is raised under a variety of conditions for feeding silkworms (*Bombyx mori* L.) to generate raw silk production. While the huge existing trees are exploited by lopping the branches for collecting leaves in the state of Jammu and Kashmir it is mostly raised as a bush in the Southern states (Karnataka, Andhrapradesh, Telangana, Tamil Nadu & Kerala) and West Bengal, which together accounts for over 90% of silk production of the country. Even as bushes, they are raised under a variety of conditions in different agro-climatic regions. In Karnataka it is raised as pit system of plantation with 90x90cm spacing raised entirely in rainfed and paired row/ IJ spacing [(3'x2')x5'] in irrigated conditions (Dandin *et al.*, 2003). In parts of South Karnataka (Chamrajanagar, Hassan and Tumkur Districts), North Karnataka (Chikkaballapur, Haveri and Yadagiri Districts) and Eastern parts of Karnataka (Bangalore Rural and Kolar District) where intensive cultivation of mulberry is practiced under heavy manuring and irrigated conditions with closed system of planting (30x60cm). Besides spacing, there is also considerable difference in the method and frequency of pruning.

Spacing of crop plants mainly depends on their growth habits however; the magnitude of growth is governed by edaphic and climatic factors such as spacing, light, aeration (Ramakant *et al.*, 2001; Sudhakar *et al.*, 2018). Light plays an important role in photosynthesis of the plants and thus ultimately decides the dry matter accumulation and vegetative growth of the plants (Singh and Singh, 1991). Krishnaswami *et al* (1971) reported that growth and development of silkworm larvae, *Bombyx mori* L. and the economic characters of their cocoons are greatly influenced by the nutritional content of mulberry leaves. Proper spacing and consequent plant population per hectare has been recognised as one of the important factor in determining the leaf yield (Kasiviswanathan and Sitarama Iyengar, 1970). Mulberry (*Morus alba* L.) leaf production is often limited by the amount of available soil moisture and it can be increased by providing timely irrigation.

Experimental findings reveal that irrigation increased leaf yield of mulberry plants by about 68%. Hence, increase in leaf yield and water productivity of mulberry is possible by improved methods of irrigation. The gap between water demand and supply is increasing year after year and declining in availability of ground water further aggravate the situation causing major threat to agriculture globally. Prolonged drought stricken atmosphere in Karnataka compelling the sericulturists in shrinking the mulberry cultivation and either preventing or reducing the silkworm rearing in summer seasons. The reasons for low availability of irrigation water are irregular and inadequate rainfall, short spell down pouring >50% annual rainfall in single or multiple days heavy drowning and inadequate ground water recharge for bore wells leaving the recurrence of drought condition for prolonged period (Shankar and Shivakumar, 2000).

II. SERICULTURE PRACTICE IN SOUTHERN INDIA

Sericulture in Southern part of India such as Karnataka, Andhra Pradesh, Tamil Nadu and some of the pockets of Kerala is an age old practice. Out of the 4 states Karnataka is remaining on the top position in regard to the production of raw silk (9571mt) followed by Andhra Pradesh (5970mt), Tamil Nadu (1914mt) and Kerala (11mt) (Anonymous, 2017).

Since 4 decades the South Indian sericultural farming community was recommended paired row system of cultivation [(60x90)x150cm] accommodating 13,888 plants/hectare where the sufficient water is available to feed 1.5 to 2.5 lit/plant through channel irrigation. But slowly the following situations are compelling the farmers to bring drastic changes in their farming style:

- Monsoon reduced to 50% followed by uncertain, unwanted and untimed rain fall leading to wastage of downpour water.
- Otherwise maximum rainfall drenched in a very short span of the season compelling the farming community experience drought stricken conditions for rest of the season.
- Further, due to insufficient water for irrigation and drought stricken conditions farmers failing to harvest required quantity of quality leaf incurring silkworm rearing failures.
- Moreover, the ground water level has gone down to >1500ft, at times further depths of bore well drillings resulting no water incurring huge expenditure for futile exercises.
- Further, man power availability has become a big crisis due to urbanization.
- Narrow plant spacing minimizing the mechanisation due to which huge weed growth, hardpan formation, prevailing subsurface rooting (instead deep rooting) causing wilting in drought spells and production of low and poor quality leaf (**Fig. 1**).



Figure. 1: Paired row spacing with unmanageable weeds & wilting of leaf in dry spell periods.

Under the above circumstances the sericultural farming community in Karnataka are compelled to adopt tree mulberry in wider spacing such as 5'x5', 6'x6', 8'x3', 8'x5' & 10'x10' so on convenient for mechanized cultivation and maintained either in rain fed conditions or semi irrigated system through the use of Affordable Micro Irrigation Technologies (AMITs) (Sudhakar *et al.*, 2018a). In this system of cultivation the added advantages are providing plant wise manure, fertilizer & water and succeeding uniform enhanced quality of mulberry leaf and cocoon production (**Fig. 2**). As there is no any specific technology or package of practices for tree mulberry farming in suitable spacing with economically viable number of plants and their training of tree mulberry farms is lacking. Further, required doses of manure and fertilizers for uniform and enhanced quality leaf suitable for bivoltine sericulture is also lacking among the farming community. Hence, it was essential and imperative evolve a suitable technology for tree mulberry farming and recommend suitable package of practices to combat with drought stricken conditions and produce enhanced quality of leaf and cocoon production even under difficult conditions was badly in need by the South Indian farming community.

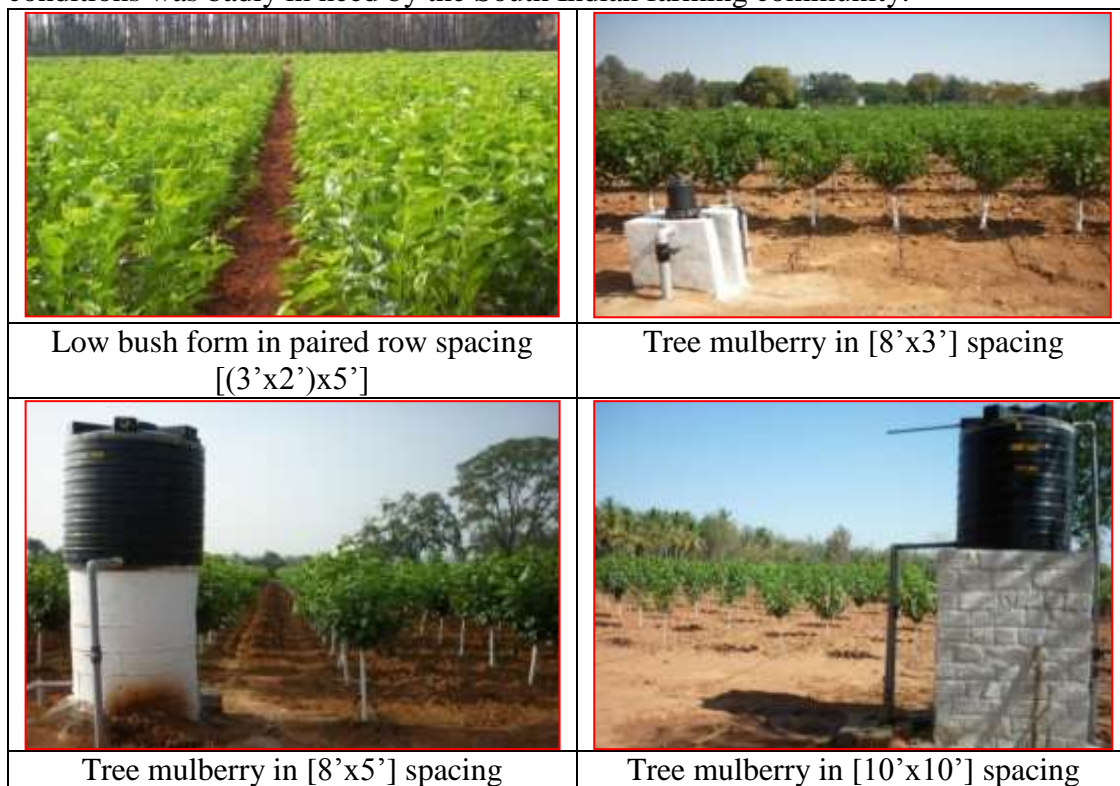


Figure 2: Mulberry in lowbush and tree farmings in varied geometries maintained under AMITs.

III. EXPERIMENTATION ON TREE MULBERRY FARMING

Undertaken long term studies in established tree mulberry gardens planted in varied geometries at Regional Sericultural Research Station, Bangalore, Karnataka to evolve suitable recommendation to the farming community (Sudhakar *et al.*, 2018; Dandin *et al.* 2003). Sudhakar *et al.* (2018) observed that tree mulberry farms in wider spacing (8'x3') with 4547 plants/ha of plants resulted in higher leaf yield (67.07mt/ha/yr) followed by paired row spacing in low bush farm with 13,888 plants/ac (60.14mt/ha/yr) and tree farm in 8'x5' with 2728 plants (51.17mt/ha/yr). However, significantly reduced no. of plants 92.1% compared to paired row spacing and 75.9% over 8'x3' spacing planting with 1093 plants/ha under 10'x10' spacing resulted in low leaf yield (21.08mt/ha/yr) causing reduced no. of DFLs brushing inferring economically not viable to practice by the sericulturists (Fig. 3 & 4).

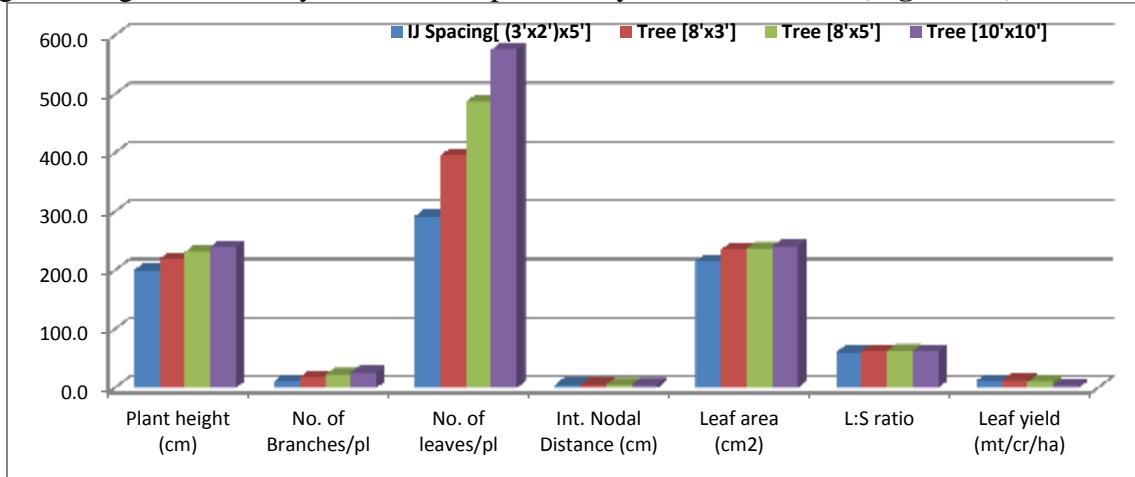


Figure. 3: Influence of tree mulberry planted in varied geometries on the plant growth and leaf yield.

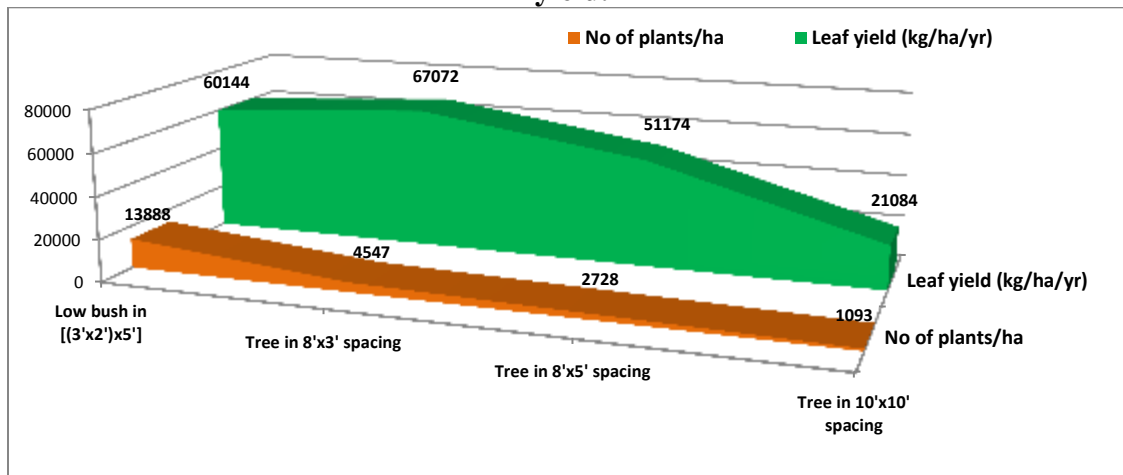


Figure. 4: Leaf yield of mulberry in different farms as influenced by plant population and spacing.

Though the number of plants/ha reduced significantly in 8'x3' (75.9%/ha) spacing, 8'x5' (80.4%/ha) and 10'x10' (92.1%/ha) compared to paired row spacing (13,888/ha) but improved plant growth and leaf yield/ha significantly. Even though in Tree farms of plantation accommodated reduced number of plants/ha planted in wider spacing but yield of foliage per plant was not reduced proportionately because of yield contributing factors *viz.* number of branches, length of shoot, number and weight of leaves/ plant having been compensated to a considerable extent. It is understood that though plant wise yield and nutritive parameters are superior over paired row spacing in tree [10'x10']

but plant population is also important to achieve the sustained leaf yield (Fig. 3 & 4). The same was pointed out by Hasegawa (1967), stating that the relation of plant density and yield was variable. Thus it can be inferred that with the increase in pruning height in tree farm plantation there was corresponding increase in the leaf yield compared to the low bush (15cm) pruning. Studies carried out elsewhere have indicated improved plant growth and increased leaf yield due to higher crown (pruning) height against the low height (Choudhury *et al.*, 1991; Fotadar *et al.*, 1995; Iwata, 1977; 1981; Katsuochoiyamna, 1970; Katsuochoiyamna *et al.*, 1976; Satoh, 1968). Significant variation was observed in case of leaf quality parameters such as leaf moisture in the medium leaves and total chlorophylls compared to the control plots. Significantly increased moisture level was observed in case of 8'x4' spacing (80.34%) followed by 10'x10' (80.31%) and 8'x3'(78.56%) compared to the paired row spacing plots (77.24%). Similar trend was observed in case of total chlorophylls. However, no variation was observed in case of leaf moisture content in the chawki leaves (Table 2). No marked variation was observed in the commercial silkworm rearing parameters due to feeding of leaves harvested from paired row as well as in tree farming (Fig. 5).

Table 2: Leaf quality parameters of mulberry as influenced by mulberry farming planted in varied geometries.

Parameters	Mulberry in varied geometries				CD at 5%
	Paired row [(3'x2')x5']	Tree 8'x3'	Tree 8'x5'	Tree 10'x10'	
Number of Plants/hectare	13888	4547	2728	1093	--
Leaf moisture in medium leaves (%)	77.24	78.56	80.34	80.31	1.88
Leaf moisture in chawki leaves (%)	82.87	84.22	83.38	82.76	NS
Total Chlorophylls (ppm/gm)	2.58	3.32	3.35	3.20	0.08

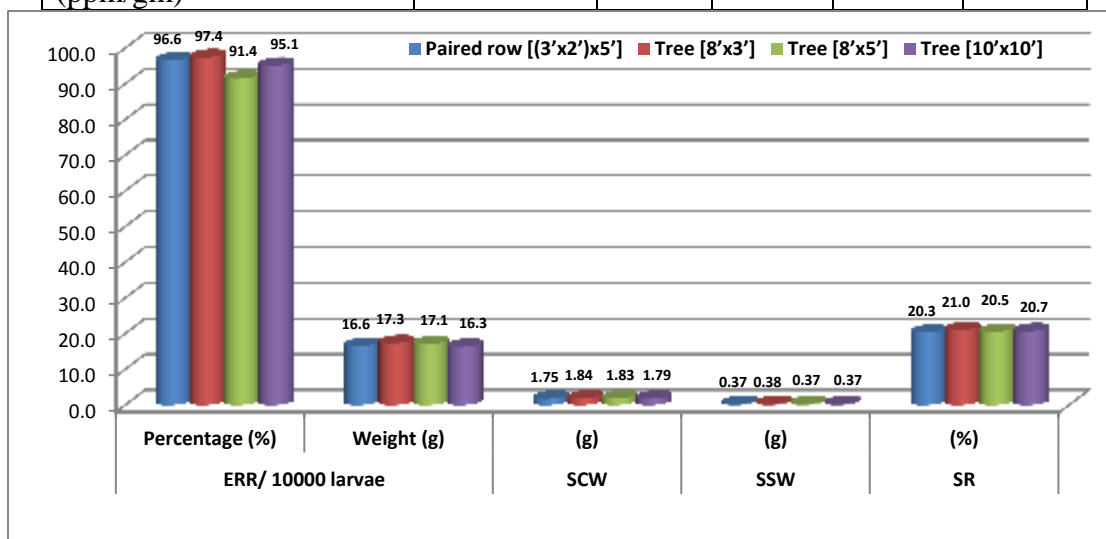


Figure. 5: Influence of tree mulberry raised in varied geometries on the silkworm rearing and commercial parameters

Further, the cost benefit ratio of leaf production assessed due to imparting of tree mulberry in varied spacing gave encouraging results. Tree mulberry in 8'x3' spacing gave highest C:B ratio (1:3.2) followed by 8'x5' spacing (1:2.4) and Paired spacing (1:1.9). However, no benefit and no loss were noticed in case of 10'x10' spacing (1:1). Moreover, comparative % of financial gain over paired row spacing was gave significant raise in 8'x3' and 8'x5' (157.6% & 126.1%), where as it has resulted in

negative trend in 10'x10' spacing (-35.1%). Cost benefit ratio in silkworm rearing under varied tree spacing also gave the similar trend as observed in leaf production (**Table 4**). Though least benefit was recorded in case of leaf production in tree mulberry (10'x10' spacing) but income due to cocoon production and cost: benefit ratio resulted on par with paired row spacing indicating that plant population has its own importance in the production of sustainable quality leaf as pronounced by Hasegawa (1967) statement as '*decline in yield with a decline in plant population density*'.

Table 4: Cost of cultivation and bivoltine cocoon production as influenced by mulberry grown under varied geometries.

Sl No	Activity/ Inputs/ Materials	Rate (Rs)	Plantation in Varied Geometries			
			Paired row [(3'x2')5']	Tree farm (8'x3')	Tree farm (8'x5')	Tree farm (10'x10')
A. Mulberry Cultivation Cost/ hectare:						
1	No. of Plants/ha	--	13,888	4,547	2,728	1,093
2	FYM (20 & 10MT/ha	1250.0	25,000	12,500	12,500	12,500
3	Fertilizers: (@ NPK 350:140:140kg/ha/yr)					
	Ammonium Sulphate (AS) (100 & 50%)	13.2	23100.0	11550.0	11550.0	11550.0
	Single Super Phosphate (SSP) (100 & 50%)	8.4	7350.0	3675.0	3675.0	3675.0
	Muriate of Potash (MOP) (100 & 50%)	11.58	2779.2	1389.6	1389.6	1389.6
4	Application of FYM (Rs 250/- per MD; 16 & 10MD)	250/-	4,000.0	2,500.0	2,500.0	2,500.0
5	Application of Chemical fertilizers (10 & 6 MD)	250/-	2,500.0	1,500.0	1,500.0	1,500.0
6	Tractor Plough (Rs/ha x 5 times)	2500/once	12,500.0	10,000.0	10,000.0	10,000.0
7	Channel making by tractor (@Rs 2000/-ha x 5 times)	2000/once	10,000.0	--	--	--
8	Irrigation: (Channel 200MD/Drip (50MD)	250/-	25,000.0	12,500.0	12,500.0	12,500.0
9	Shoot harvest (@ 200MD/ha/yr)	250/-	50,000.0	50,000.0	50,000.0	50,000.0
10	Tax Paid on Land (Rs. 100/ha)	100.0	100.0	100.0	100.0	100.0
	TOTAL	--	1,62,329.2	1,05,714.6	1,05,714.6	1,05,714.6
11	Leaf yield (kg/ha/yr)	--	60,145.0	67,072.0	51,174.0	21,084.0
12	Cost of leaf (@ Rs. 5/- per kg)	--	3,00,725.0	3,35,360.0	2,55,870.0	1,05,420.0
13	Net Gain through leaf production	--	1,38,395.8	2,29,645.4	1,50,155.4	-294.6
14	Cost: benefit Ratio of leaf	--	1 : 1.9	1 : 3.2	1 : 2.4	1 : 1.0

production						
B.	Silkworm Rearing/					
	Hectare:					
15	No. of DFLs to be brushed/ha/yr	--	4375	3125	2500	1250
16	Cost of Chawki (Rs.2000/100DFLs)	--	875000	62500.0	50000.0	25000.0
17	Cocoon Yield (60 & 80 kg/100DFLs)	--	2625	2500	2000	1000
18	Cost of Cocoon /ha/yr (@ Rs. 350 & 500/kg)	--	9,18,750.0	12,50,000.0	10,00,000.0	5,00,000.0
19	Input cost of each rearing (@ 25%)	--	2,29,687.0	1,64,062.0	1,31,249.70	52,499.9
20	Net Gain due to rearing	--	6,89,063.0	10,85,938.0	8,68,751.0	4,47,500.1
21	Comparative gain over paired row spacing:	--	--	157.6%	126.1%	-35.1%
22	C : B Ratio of varied spacing	--	1 : 2.3	1 :4.6	1 :4.2	1 : 3.2

Man Day (MD) = Rate/MD @ Rs.250/- per MD; ***Tractor ploughing:** @ Rs. 2,500/ ha for paired row spacing, Rs.2,000/tree mulberry farm;

Irrigation: For flood: @3MD/irrigationx10times/cropx5crops);**Drip:** @1MD/irrigationx10 timesx5 crops; **Fertilizers:** Rec.AS, SSP & MOP & FYM (@350:140:140kg & 20mt/ha/yr) for paired row, Whereas the same applied 50% in tree mulberry; ****DFLs brushing:** Paired row @875DFLs/ha/crop; 8’x3’ @625DFLs/ha/crop; 8’x5’ @ 500DFLs/ha/crop & 10’x10’ @250DFLs/ha/crop.

Suitable package of practices evolved for tree farming:

With the above findings the South Indian Tropical sericulturists are advised to adopt the following package of practices as depicted through pictorial (**Fig. 4, 5**) and **Table 5** for their benefit, social economic upliftment and supporting the Indian economy.





Figure. 4: Tree mulberry plantation & training for enhanced uniform quality leaf & bivoltine cocoon production.

Table 5: Package of practices evolved to adopt tree mulberry for the Sothern Sericultural Farming community.

1	Necessity of Tree mulberry	:	<ul style="list-style-type: none"> • Poor rain fall, limited water resource for mulberry cultivation; expensive & non availability of manpower; • Inconvenient paired row spacing for mechanization causing huge weeds leading to multiple pathogen attack on mulberry • prolonged dry spell leading to wilting of leaf, inadequate & poor quality leaf production • Due to the above skipping or minimizing the rearing during the drought spell (<i>i.e</i> Oct-Dec & Jan-May).
2	How tree mulberry beneficial:	:	<ul style="list-style-type: none"> ✓ Tree mulberry withstands drought conditions due to its firm tree form and deep root system, ✓ Perform well in all seasons even under limited water availability and low rain fall circumstances ✓ Minimizes manpower drudgery on irrigation and cultivation due to mechanization, ✓ Uniform & enhanced quality mulberry leaf ideal for silkworm rearing leading to quality cocoon with enhanced market rate, ✓ Minimum pest & diseases occurrence due to aeration and tree habitat, ✓ Economizes plant wise fertilizers & manure application avoiding wastage, ✓ Last but not the least convenient for mechanized tillage by using Power Tiller, Mini-Tractor & Tractor.
3	Suitable season to undertake tree mulberry	:	<ul style="list-style-type: none"> ➤ With the onset of monsoon (June-July) land preparation and plantation can be planned. ➤ 5-6 months old V₁ or G₄ saplings planted in 1ft. to 1.5 ft. deep pits supplementing with >1kg FYM. ➤ Suitable spacing like 4'x6'/5'x6' for small & medium farmers & 4'x8'/5'x8'/4'x10'/5'x10' for large farmers accommodating 850 to 1800 plants/acre for mechanization and economically viable farming (Fig. 5) ➤ While plantation saplings can be cut up to 1ft. to 1.5ft. height from the ground for convenient operation even up to 10-15yrs. ➤ Monsoon showers helps plants to establish in 5-6 months. During establishment plants trained removing unwanted branches (from the bottom bottom) to give crown form (Fig. 4). ➤ If the maintenance appropriate 1st harvest is possible after 6 months of plantation and

		<p>used for rearing 50 DFLs/acre as first rearing.</p> <ul style="list-style-type: none"> ➤ 2nd harvest after 9th month after plantation and reared 100DFLs/ acre; 3rd harvest after 12th month of plantation brushing 150DFLs/acre and 2nd year onwards 5 crops schedule will be followed brushing 200-250 DFLs/acre/crop.
4	Economic gain of tree farming & silkworm rearing	<ul style="list-style-type: none"> ➤ Tree mulberry is proved to be beneficial in case of plantation as well as silkworm rearing. ➤ In plantation limited planting material, easy to plantation, maintenance and establishment. ➤ Economic in maintenance with drip irrigation, reduced level of manures and fertilizers without wastage. ➤ Easy maintenance compared to paired row spacing due to mechanization with less drudgery of manpower.
5	Added advantage in tree mulberry	<ul style="list-style-type: none"> ❖ Enhanced uniform quality, disease & pest free leaf production leading to successful bivoltine sericulture. ❖ No rearing crop losses with enhanced uniform quality of Bivoltine cocoon production with increased market rate. ❖ Enhanced cost benefit ratio in case of leaf production (1:3.0 in 8'x3' & 1:2.3 in 8'x5' over IJ Spacing (1:1.8). ❖ Increased C:B ratio of cocoon production i.e. 1:3.8 in 8'x3', 1:3.5 in 8'x5' & 1:3.1 in 10'x10' spacing compared to paired row (1:2.3) (Table 4). ❖ Further, Central & State Sericulture Govt. decided to support <i>Tree mulberry</i> farming among farmers by all means.

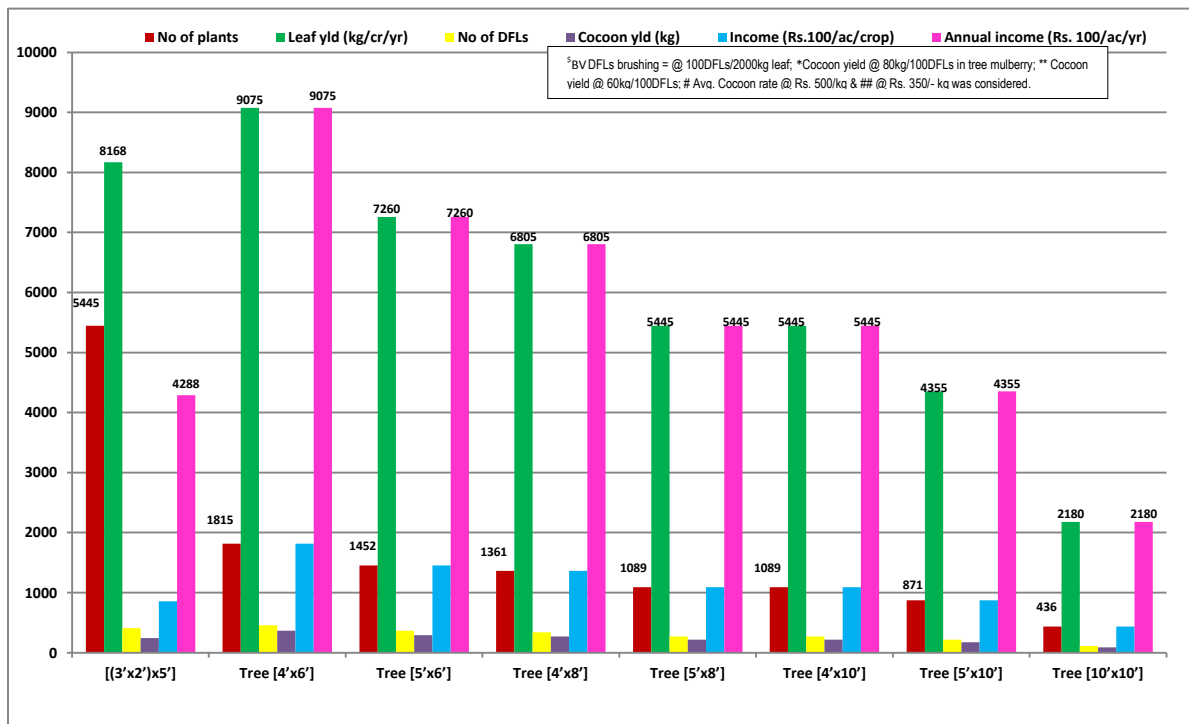


Figure. 5: Projected DFLs brushing, cocoon yield and economic benefit due to adoption of tree mulberry in varied geometries.

IV. CONCLUSION

It could be inferred that the plant population plays an important role in production of sustainable leaf. Economically viable number of plant population to sustain with the available water resource without compromising the quantum of DFLs brushing (625-750DFLs/ hectare/crop) and performing rearing around the year will be the ultimate objective. The above results have generated a ray of hope that through the tree mulberry farming planted in 8'x3' spacing with 4547plants/hectare supplementing with plant wise application of 50% reduced doses of fertilizers and manure cultivated with limited water supply is an ultimate to the South Indian farming community even under drought stricken atmosphere prevailing areas of India. Further, the tree mulberry farming has shown its resistance and tolerance level to the extreme drought prone situations because of its deep root system with strong and well established firm aerial stem promoting silkworm rearing in all the seasons, whereas the same was proved not possible in case of paired row spacing with more number of plants (13,888) indicating difficult to maintain under scarce water availability and also showing wilting symptoms in summer crops forcing the farming community to with draw silkworm rearing crops. Therefore, the tree farm of mulberry is an imperative to not only for enhanced uniform quality and assured leaf production but also to combat with acute drought stricken climatic conditions.

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BIBLIOGRAPHY

- [1] Anonymous, 2017. Annula Report. Published by Central Silk Board, Bangalore, Karnataka. Pp. 1- 100.
- [2] Dandin, S.B., Jayaswal, J. and Giridhar, K. 2003. Handbook of Sericulture Technologies (Recommended for South Indian States). Pp. 259. Published by Central Silk Board, CSB Complex, BTM Layout, Madivala, Bangalore, Karnataka.
- [3] Fotadar, R.K., Anil Dhar., Shiva Dhar. And Mukherjee, P. Effect of different pruning heights on the mulberry yield and silkworm rearing. Indian J. Seric., 34(2): 105-109.
- [4] Choudhury, P.C., Shukla, P., Ghosh, A., Mallikarjuna, B. and Sengupta, K. 1991. Effect of spacing crown height and method of pruning on mulberry leaf yield, quality and cocoon yield. Indian J. Seric., 30(1): 46-53.
- [5] Hasegawa, Kiyoto. 1967. Study on the relations between population density and yield in the mulberry field. Bull. Seri. Exp. Station. 22: 28-29.
- [6] Iwata, E. 1978. On the study of primary pruning to train low cutting in mulberry plants. Bull. Seric. Expt. Stn. (Tokyo). 27: 397-426.
- [7] Iwata, E. 1981. Studies on the growth of regenerated shoot after intermediate pruning and its application to cultivation of mulberry trees. Bull. Seric. Expt. Stn. (Tokyo). 28: 393-398.
- [8] Kasiviswanathan and Sitarama Iyengar, M.N. 1970. Effect of plant densities, methods of leaf harvest and nitrogen fertilization on the leaf yield of irrigated mulberry in Mysore State. Indian J. Seric. 9(1): 43-48.
- [9] Katsuochoiyamna. 1970. Studies on the function of the root of mulberry plant in relation to shoot pruning at harvesting. Bull. Seric. Expt. Stn., 24(1): 125-132.
- [10] Katsuochoiyamna., Sukimitsu Sarita and Mitsumara Satoh. 1976. The role of mulberry leaves remaining after shoot pruning in dry matter production and the effect of shading. Bull. J. Seric. Sci. Jpn., 45(5): 437-442.
- [11] Krishnaswami, S., Kumararaj, S., Vijayaraghavan, K. and Kasiviswanathan, K. 1971. Silkworm feeding trials for evaluating the quality of mulberry leaves as influenced by variety, spacing and nitrogen fertilization. Indian J. Seric., 10(1): 79-89.
- [12] Ramakant, Singh, B.D., Sarkar, A. and Hasegawa, K. 2001. Effect of different plant geometry and levels of fertilizer on yield of semi-mechanised mulberry garden under irrigated condition for corporate sector. Proc. Natl. Semi on Mulberry Seri Research, India, pp. 288-292.

- [13] Shankar, M. A. and Shivakumar, H. R. 2000. Drip and Fertigation to the mulberry. *Technical Bulletin*. Dry Land Agriculture Project & Department of Sericulture, University of Agricultural Science, GKVK, Bangalore, Karnataka, India. Pp. 1-63.
- [14] Singh, Y. and Singh, M. 1991. Effect of sowing time, spacing and nitrogen levels on yield of mustard (*Brassica juncea*). *Indian J. Agron.*, 36(3): 429-430.
- [15] Sato, M. 1968. On production structure and matter production in mulberry plants. *Acta Sericologia*, 67: 1-6.
- [16] Sudhakar, P., Hanumantharayappa, S.K., Sudhakar Rao, P., Jalaja S Kumar and Sivaprasad, V. 2018. Influence of tree mulberry (*Morus alba* L.) in varied geometries on mulberry leaf and silkworm rearing” by the authors. *Int. J. Cur. Res. In Life Sci.* 7(3):1381-1386.
- [17] Sudhakar, P; Hanumantharayappa, S.K; Jalaja S. Kumar and Sivaprasad. V. 2018a. Evaluation of Affordable Micro-Irrigation Technologies (AMITs) for quality mulberry leaf production. *Green Farming*. 9(1): 176-178.